



Armed Forces College of Medicine AFCM



hypoxia & cyanosis

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INTENDED LEARNING OBJECTIVES (ILOs)



By the end of this lecture the student will be able to:

- ✓ Define hypoxia and describe its four principal forms.
- ✓ Explain the effect of each type of hypoxia on PaO_2 , PvO_2 , O_2 content and % saturation of HB with O_2 .
- ✓ Mention the effectiveness of O_2 therapy in treatment of hypoxia.
- ✓ Define cyanosis and describe its threshold.
- ✓ Explain central and peripheral cyanosis.
- ✓ Explain types of hypoxia associated with cyanosis.
- ✓ Apply the information studied in this section to solve a clinical problem or explain clinical case.

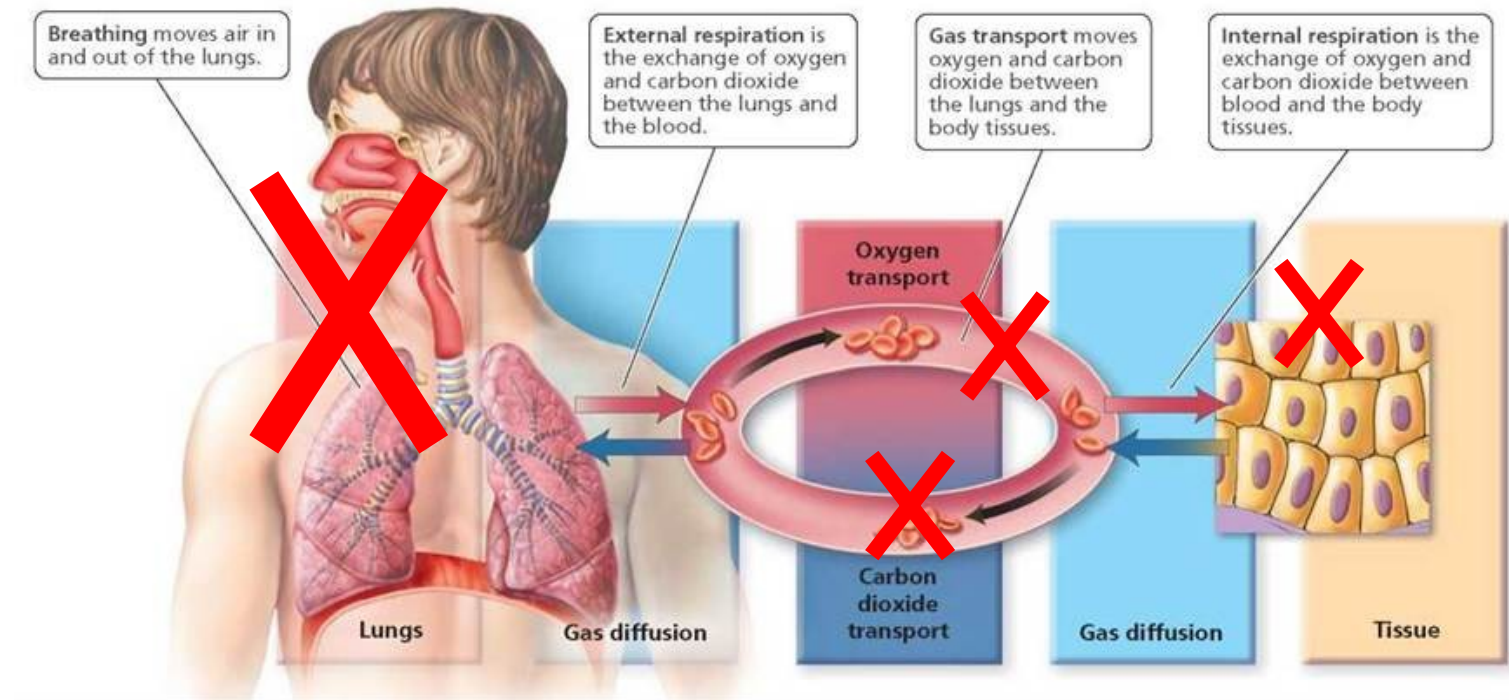


Hypoxia

➤ **Definition:** it is lack of oxygen **at tissue level.**

➤ **Types:**

Hypoxic Hypoxia



<https://schoolbag.info/biology/humans/19.html>

Histotoxic Hypoxia

Anemic Hypoxia

Stagnant Hypoxia

Hypoxic hypoxia



Definition: It is due to inadequate oxygenation of the arterial blood (Hypoxemia). It is the most common type of hypoxia.

Causes:
1- Reduced PO_2 in inspired air as in high altitude

Alveolar-arterial PO_2
gradient (A-a
gradient)



Hypoxic hypoxia



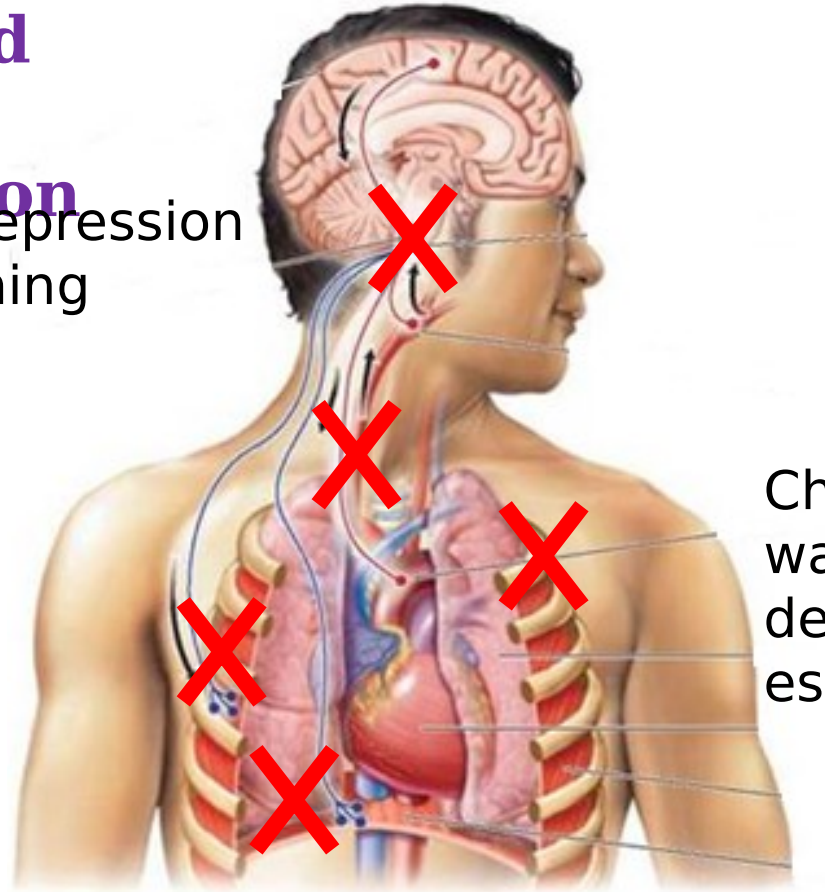
2- Generalized Alveolar Hypoventilation

Respiratory center depression
e.g. morphine poisoning

Obstructive diseases:
COPD

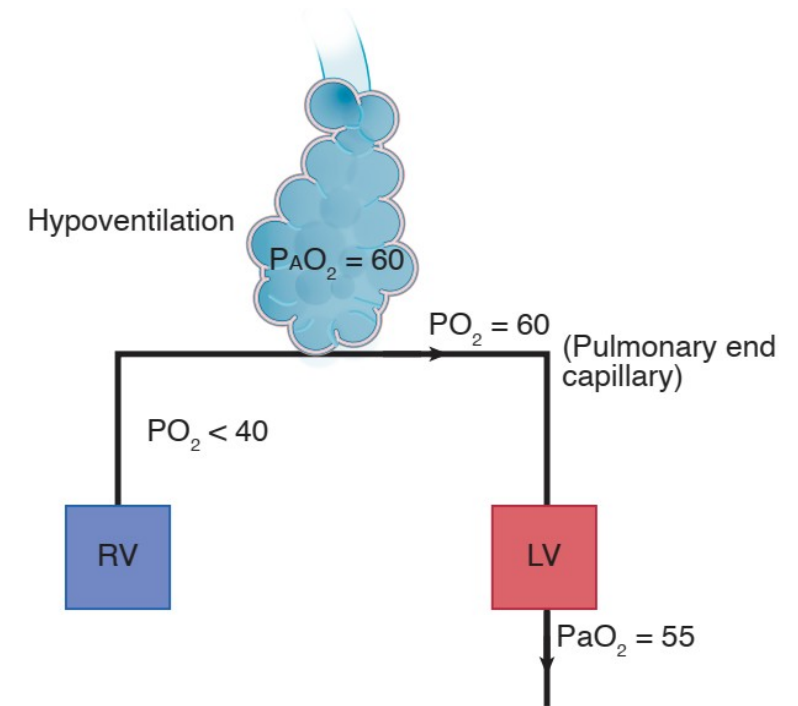
Respiratory muscle
diseases: myopathy or
poliomyelitis

Decrease
compliance: lung
fibrosis



Chest
wall
deformiti
es

<https://schoolbag.info/biology/humans/19.html>



Alveolar-arterial PO_2
gradient (A-a
gradient)

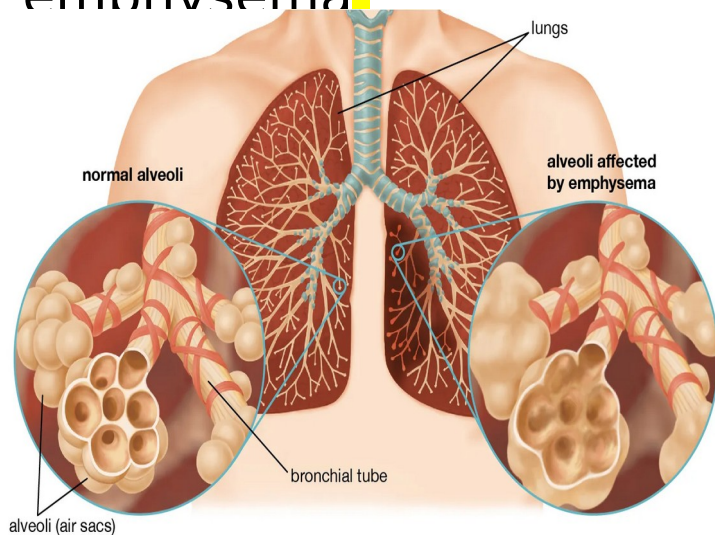
Hypoxic hypoxia



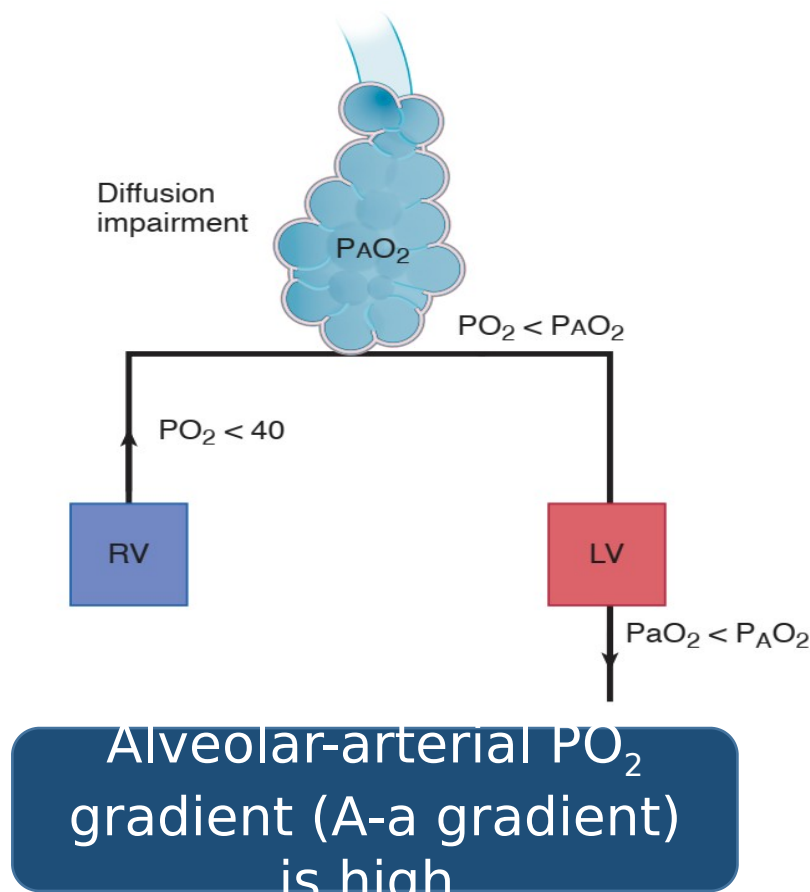
3-Impaired diffusion:

Uncommon cause of hypoxemia

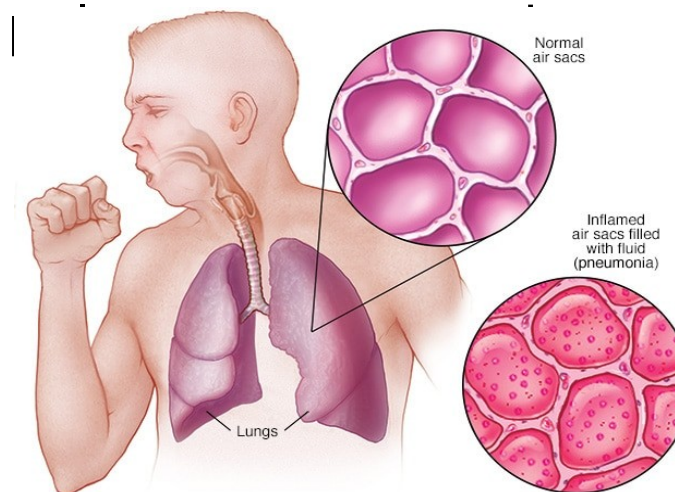
A- Decrease pulmonary surface area e.g. emphysema



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B- Increase pulmonary membrane thickness e.g. pneumonia, fibrosis and



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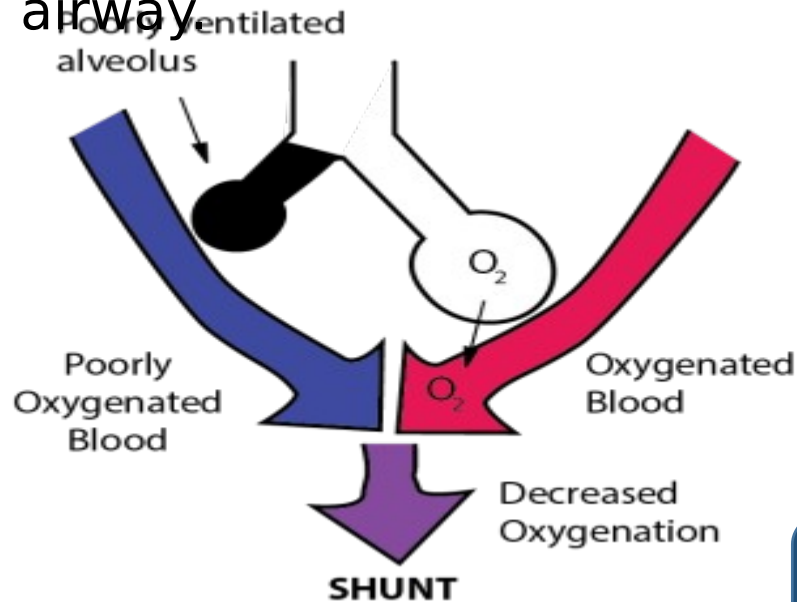
Hypoxic hypoxia



4- Venous- arterial shunt / Right to left shunt

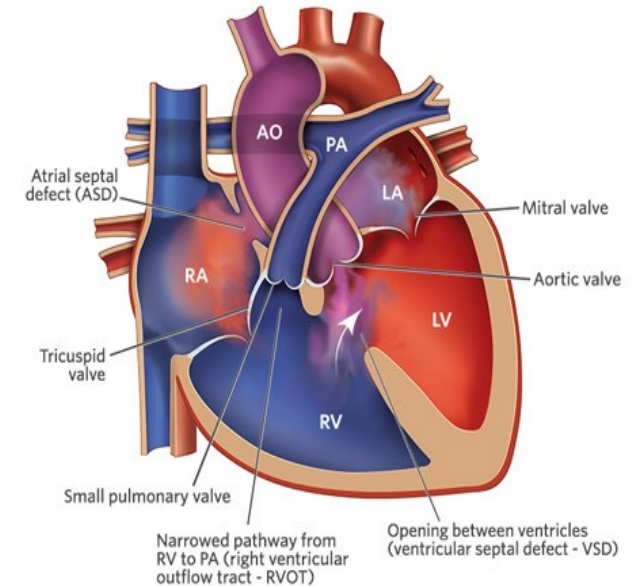
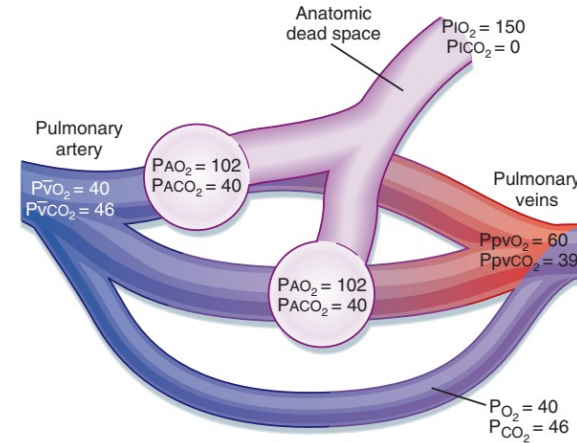
Physiological shunt

Shunts are caused by atelectatic lung regions (pneumothorax, ARDS), complete occlusion of an airway



Anatomical shunt

Congenital heart diseases such as Fallot's tetralogy and Intrapulmonary shunts



Alveolar-arterial PO_2 gradient (A-a gradient) is high

<https://www.chop.edu/conditions-diseases/tetralogy-fallot>

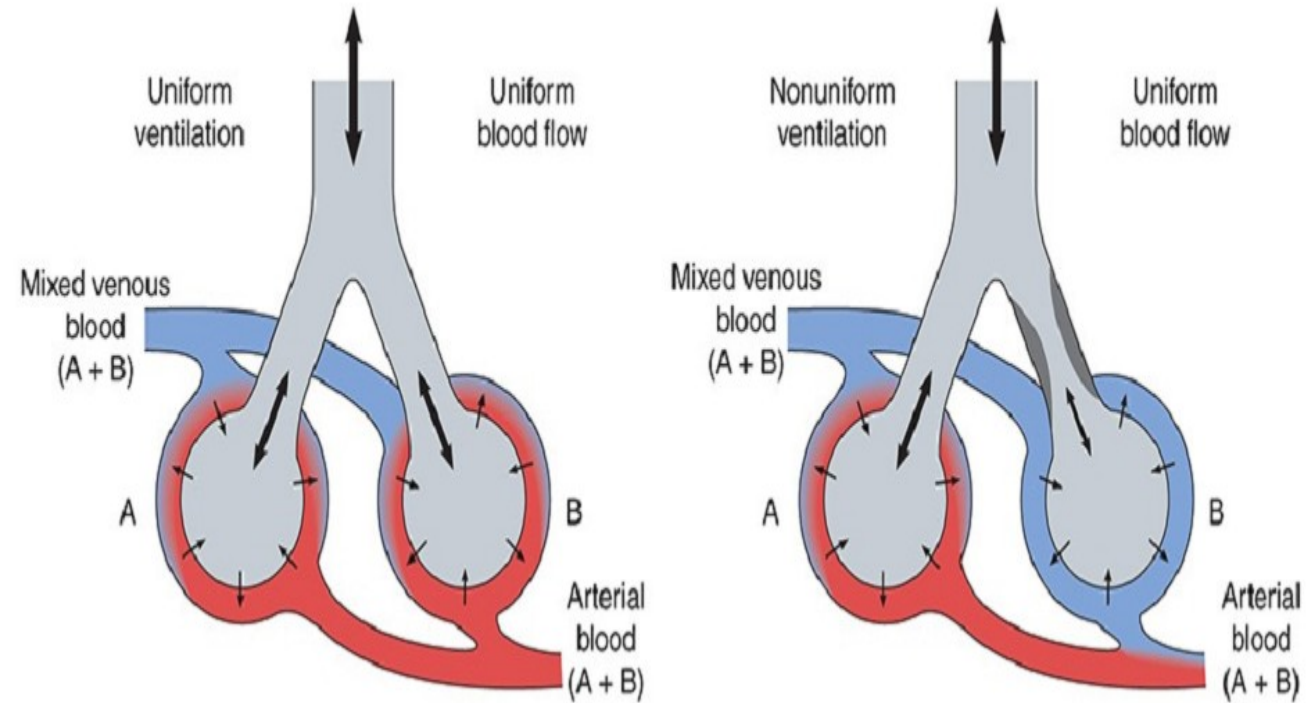
Hypoxic hypoxia



5- Ventilation perfusion imbalance

- The **most common cause** of hypoxemia.
- There are many lung diseases e.g. COPD, emphysema and pneumonia.

Alveolar-arterial PO_2 gradient (A-a gradient) is high

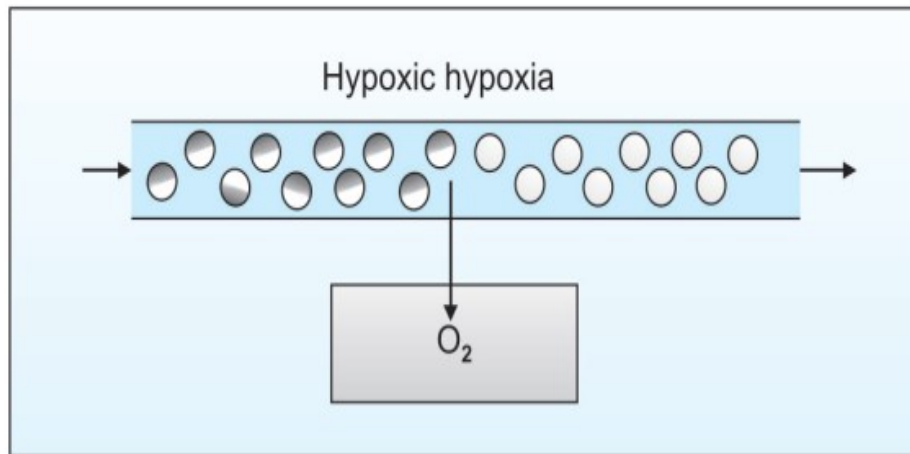
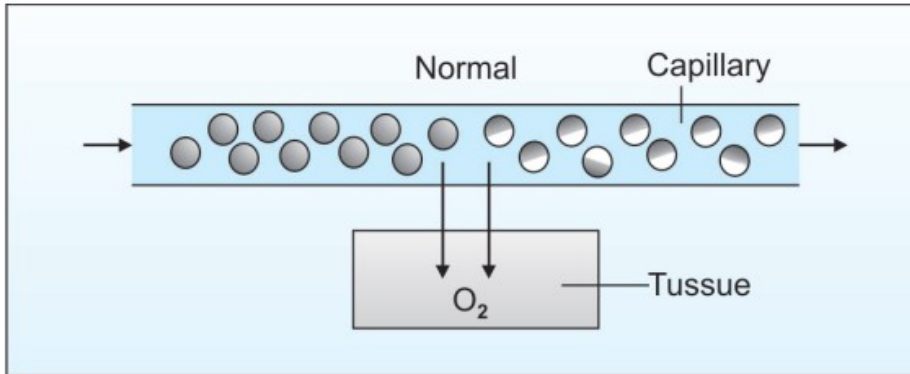


Ganong's Review of Medical Physiology, 2016

Hypoxic hypoxia



Criteria:



Arterial
blood

- Low PO_2
- Low O_2 content
- Low % O_2 saturation of hemoglobin

Venous
blood

- Low PO_2
- Low O_2 content
- Low % O_2 saturation of hemoglobin



• **Hypoventilation** is characterized by PAO_2 (alveolar O_2 tension) **Low** and PaO_2 (arterial O_2 tension) **Low**

• **Diffusion impairment** is characterized by **High** A-a gradient

Anemic Hypoxia



Definition: Hypoxia due to lack of functioning Hb (capable of carrying O₂).

Causes:

1. Quantitative: all types of anemia.
2. Qualitative:
 - CO poisoning
 - Met Hemoglobin
 - Sulf Hemoglobin

In Anemic Hypoxia the manifestation is not severe due to increase 2,3 DBG in case of anemia **Except** with **Hb deficiency is high** or during **EXERCISE** Hypoxia effect might be severe because Of the Limited activity to increased O₂ delivery to active tissue



Anemic hypoxia



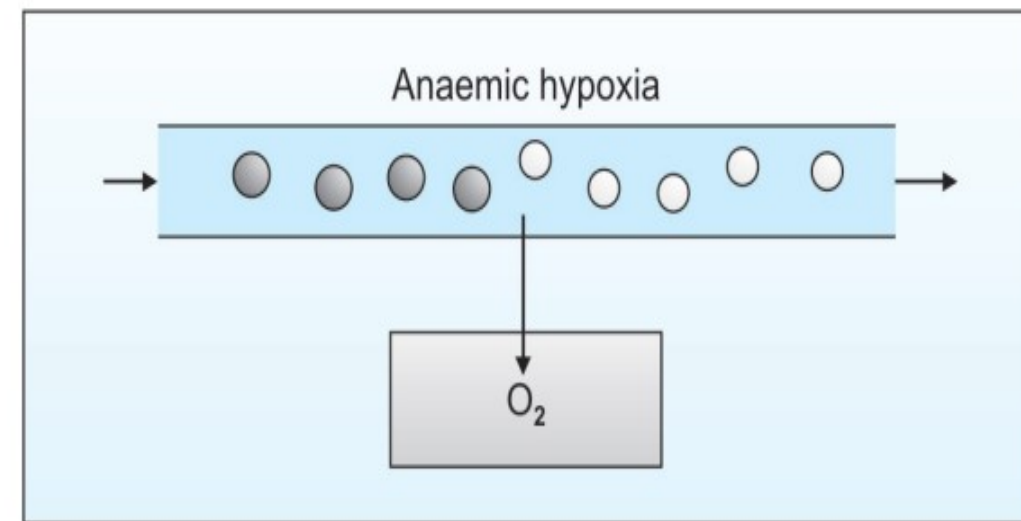
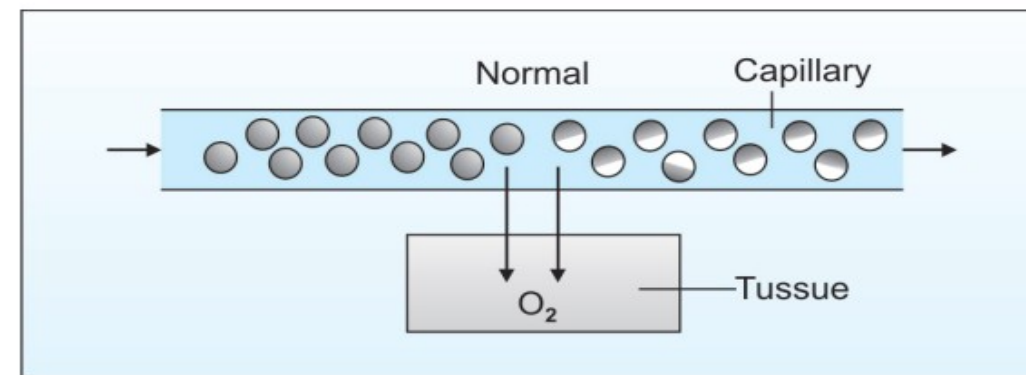
Criteria:

Arterial
blood

- Normal PO_2
- Low O_2 content
- Normal % O_2 saturation of haemoglobin

Venous
blood

- Low PO_2
- Low O_2 content
- Low % O_2 saturation of haemoglobin

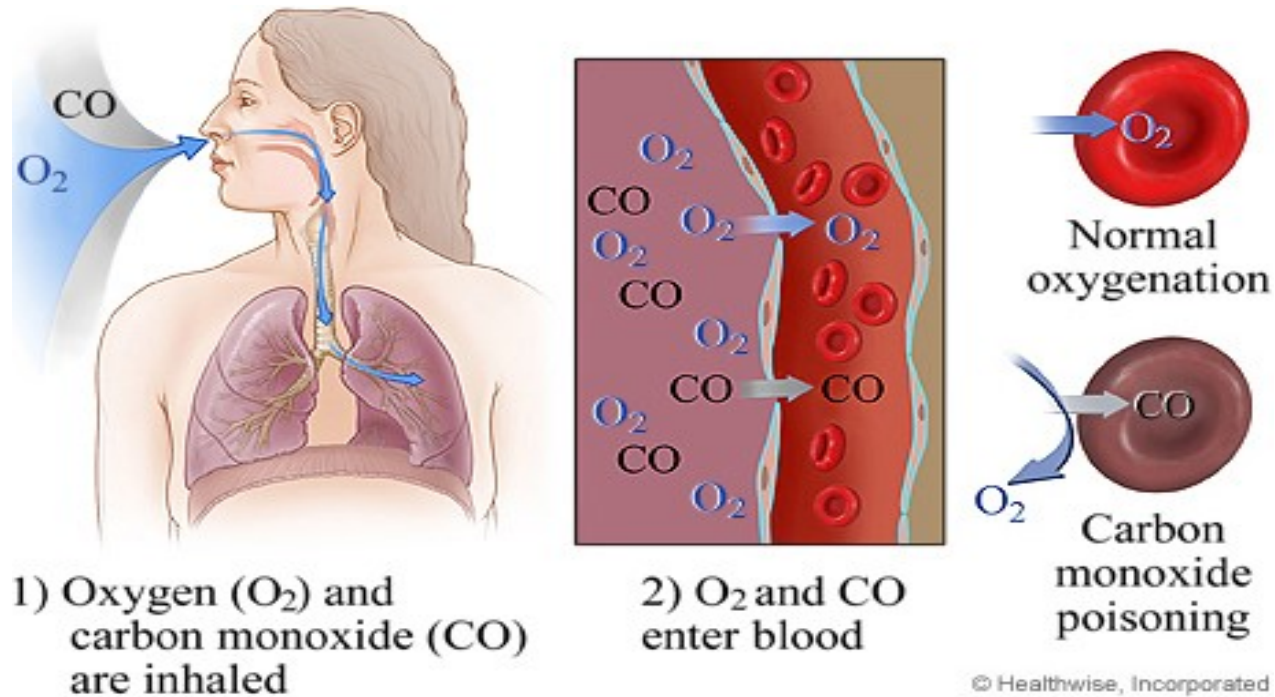


Understanding medical physiology: a textbook for medical students, Fourth Edition, JAYPEE, 2011

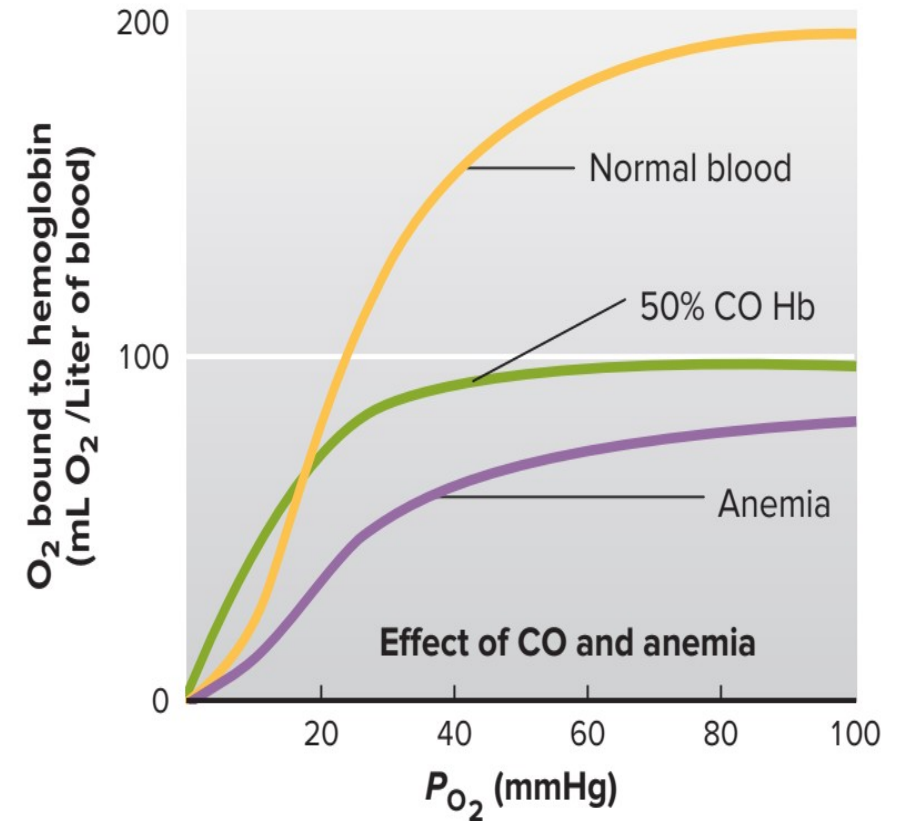
Anemic Hypoxia



CO Poisoning: It is toxic gas



<https://www.healthlinkbc.ca/health-topics/zm2552>



VANDER'S HUMAN
PHYSIOLOGY , 2023

Anemic Hypoxia



❖ *Symptoms and Signs:*

Patient experience headache, nausea, and dizziness and his skin and mucous membrane appear **cherry red** in color.

❖ *Criteria:*

- Same as Anemic hypoxia but with **low Oxygen saturation** (O_2 per g Hb) when measured with a carbon monoxide oximeter (identify the proportions of oxyHb, deoxyHb, COHgb levels).

N.B. Oxygen saturation as measured with conventional pulse oximeter is normal (as it does not differentiate between oxygenated hemoglobin and carboxy hemoglobin)



Cherry-red skin color produced by CO poisoning.

<https://lonegp.wordpress.com/2018/07/16/carbon-monoxide/>

Anemic Hypoxia



❖ ***Treatment:***

- Termination of exposure
- Artificial respiration
- O₂ therapy: Hyperbaric O₂ or 95% O₂ + 5% CO₂ to stimulate respiration
- Exchange transfusion
- Complete rest for several hours.



Hypoperfusion (stagnant) Hypoxia



Definition: Hypoxia due to inadequate blood flow or slow circulation.

Causes:

- Generalized: due to congestive heart failure or circulatory shock.
- Localized: due to vascular obstruction.

Hypoperfusion (stagnant) Hypoxia



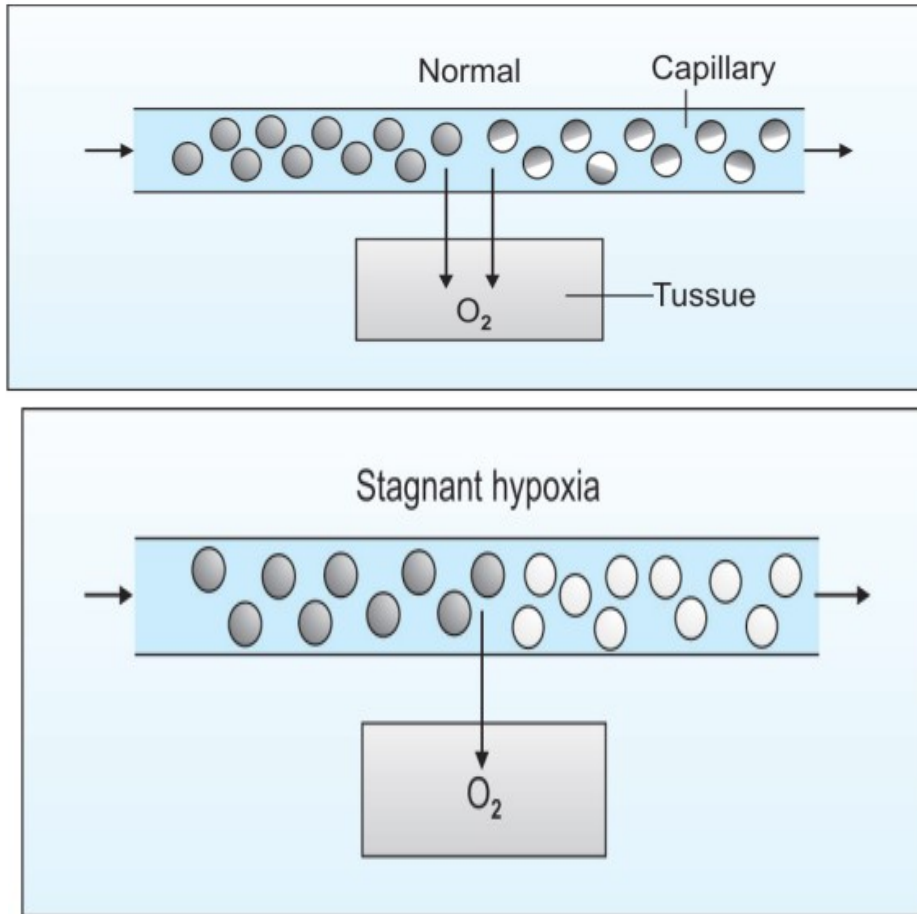
Criteria:

Arterial
blood

- Normal PO_2
- Normal O_2 content
- Normal % O_2 saturation of haemoglobin

Venous
blood

- Low PO_2
- Low O_2 content
- Low % O_2 saturation of haemoglobin



Understanding medical physiology: a textbook for medical students, Fourth Edition, JAYPEE, 2011

Histotoxic Hypoxia



Definition: It is due to inability of tissue to utilize O_2 .

Causes:

- Cyanide poisoning inhibits cytochrome oxidase.
- Alcohol poisoning inhibits cytochrome reductase.

Histotoxic Hypoxia



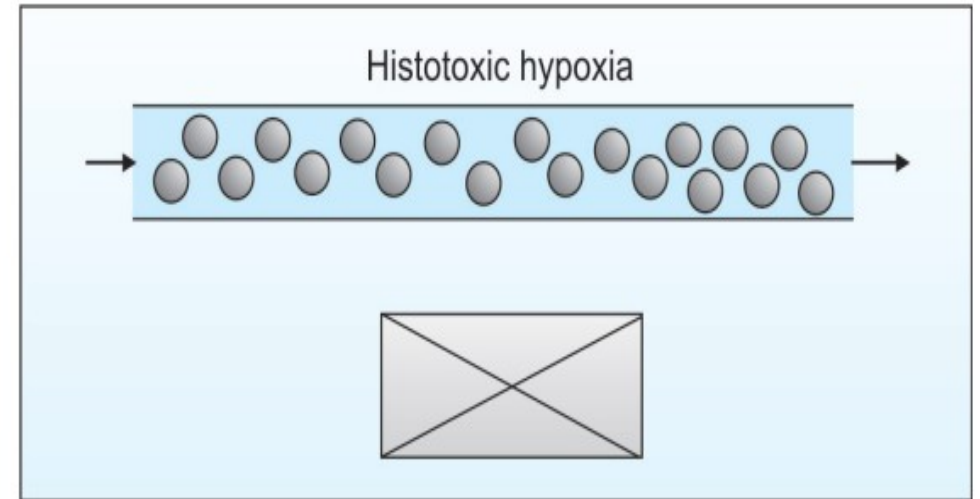
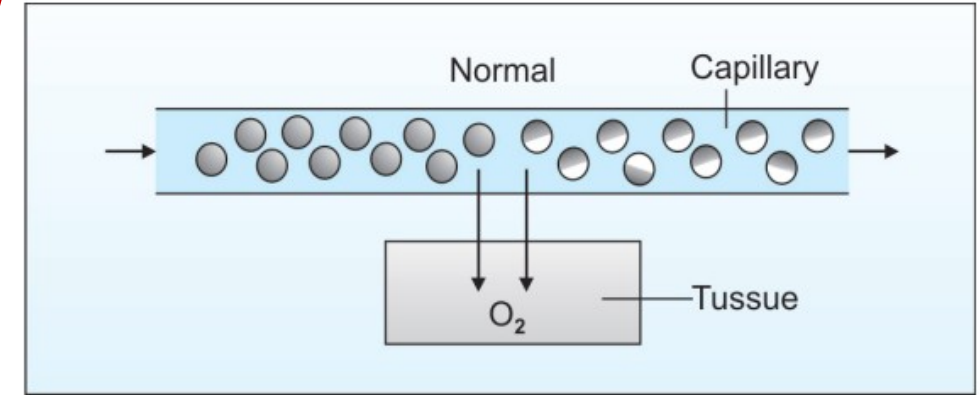
Criteria:

Arteri
al
blood

- Normal PO_2
- Normal O_2 content
- Normal % O_2 saturation of haemoglobin

Venou
s
blood

- Higher PO_2 than normal venous value
- Higher O_2 content
- Higher % O_2 saturation of haemoglobin



Understanding medical physiology: **a textbook for medical students**, Fourth Edition , JAYPEE, 2011



Treatment of cyanide poisoning:

- Injection of **methylene blue or nitrite**, forming methemoglobin, which then reacts with cyanide to form **cyanmethemoglobin**, a nontoxic compound. Which is removed by liver or kidney.

Complete:

- ***Anemic hypoxia*** is due to **Low O_2 content**

while ***ischemic hypoxia*** is due to **inadequate blood flow**



Hypoxia



➤ Effect of Hypoxia

Moderate hypoxia

1) On brain: Headache, impaired judgment, pain and drowsiness.

2) On circulation: increase heart rate and arterial blood pressure.

3) On respiration: increase respiratory rate.

4) On GIT: nausea and vomiting

Severe hypoxia

PO₂ less than

20mmHg

loss of conscious in about 20 seconds and death in about

4-5 minutes

O_2 therapy in different types of hypoxia



O_2 is highly beneficial in:

- ❑ Hypoxic hypoxia due to decrease atmospheric PO_2 , hypoventilation and impaired diffusion.
- ❑ CO poisoning

O_2 therapy will increase both **chemically combined** and



O_2 is less beneficial in:

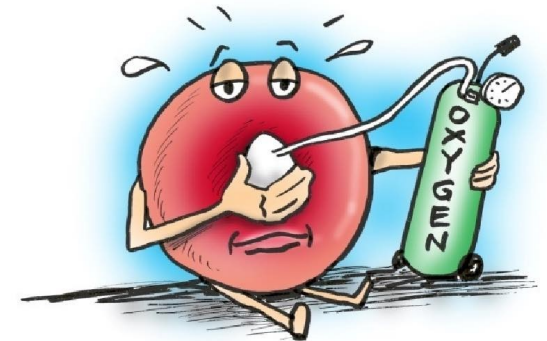
- ❑ Hypoxic hypoxia due to venous to arterial shunt.
- ❑ Anemic hypoxia due to low Hb content.
- ❑ Stagnant hypoxia.

O_2 therapy will increase **physically dissolved O_2 only.**



O_2 is not beneficial in:

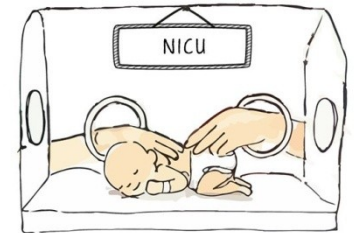
- ❑ Histotoxic hypoxia



O₂ toxicity



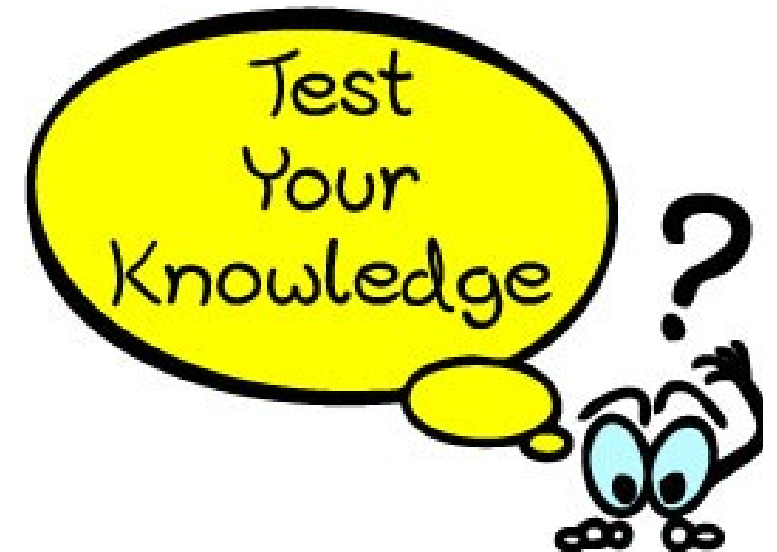
- ❑ Administration of 80-100% O₂ for
 - 8 hours irritate the respiratory tract.
 - from 8 to 48 hours damage to lungs
 - above 48 hours damage to CNS
- ❑ Administration of O₂ to **premature baby** induce vasoconstriction in retinal blood vessels (retrolental fibroplasias)
- ❑ Administration of hyperbaric O₂ (100% but under high pressure) will **accelerate the onset of toxicity.**



Choose from the following one or more correct answer:

Oxygen therapy is highly useful in which of the following?

- a. Anemia
- b. CO poisoning
- c. Cyanide poisoning
- d. Hypoventilation
- e. Pulmonary congestion



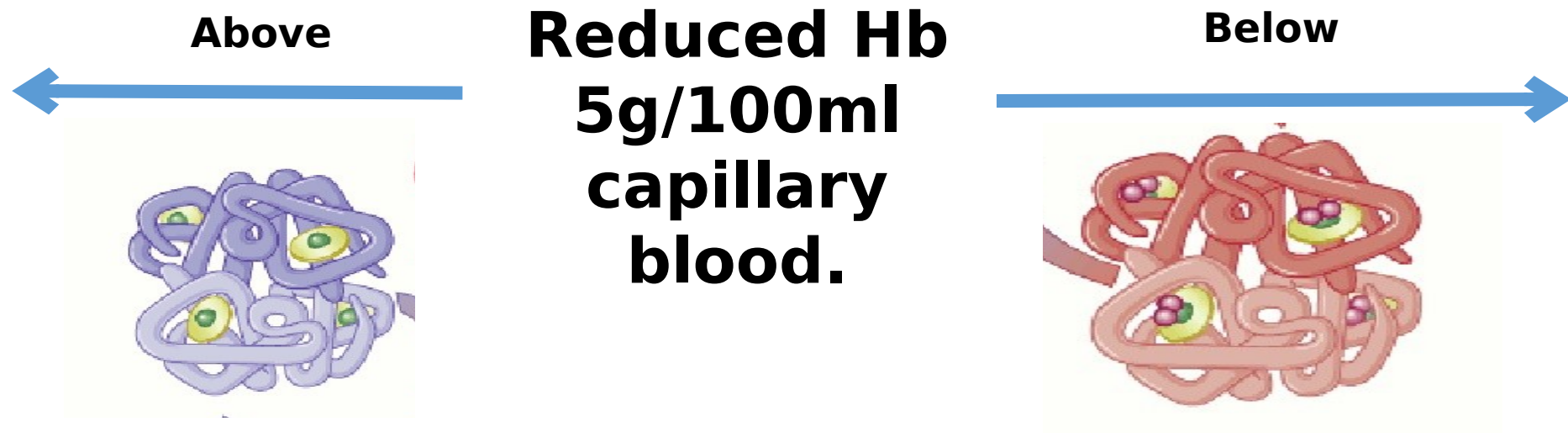
Hypoxia



		Hypoxic hypoxia	Anemic hypoxia	Stagnant hypoxia	Histotoxic hypoxia
Arterial	PO ₂	↓↓	Normal	Normal	Normal
	Content	↓↓	↓↓	Normal	Normal
	% saturation	↓↓	Normal (low in CO poisoning)	Normal	Normal
Venous	PO ₂	↓↓	↓↓	↓↓	↑↑
	Content	↓↓	↓↓	↓↓	↑↑
	% saturation	↓↓	↓↓	↓↓	↑↑
Cyanosis		Present	Absent	Present	Absent
O ₂ therapy		Beneficial in all except venous to arterial shunt ↑ Both chemical and physically dissolved O ₂	Less beneficial except with CO poisoning ↑ only physically dissolved O ₂	Less beneficial ↑ only physically dissolved O ₂	Not beneficial

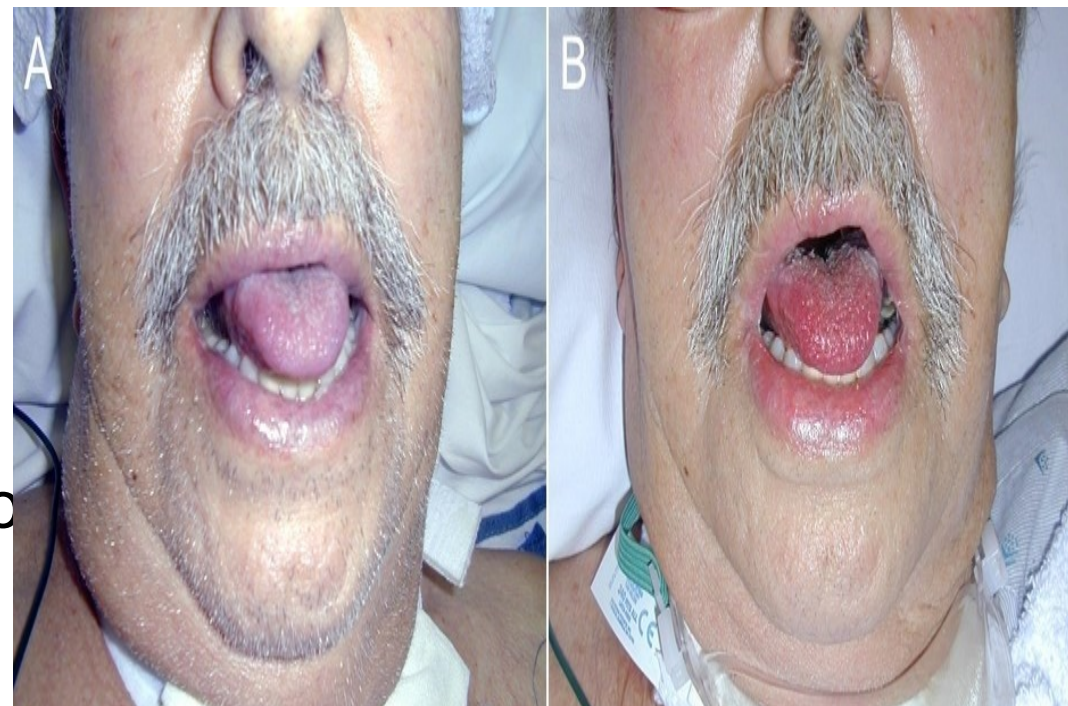
Definition: Bluish discoloration of skin, nail beds and mucous membranes due to increase of reduced Hb above 5g/100ml capillary blood.

Threshold of cyanosis:



Causes:

1. Hypoxic hypoxia: central cyanosis.
2. Stagnant hypoxia: peripheral cyanosis.
3. Asphyxia.
4. Polycythemia due to high level of Hb.
5. Moderate cold.





<http://www.swjpcc.com/imaging/2018/1/24/medical-image-of-the-week-methemoglobinemia.html>

Seen in:

- o Nail bed
- o Mucus membrane
- o For labes

CYANOSIS



Features	Central cyanosis	Peripheral cyanosis
Mechanism	(Hypoxic hypoxia) Inadequate oxygenation of systemic arterial blood due to respiratory defect. or circulatory defect e.g. cardiac right-to-left shunts (e.g. tetralogy of Fallot.	(Stagnant hypoxia) Low output states as in congestive hart failure, sluggish peripheral circulation e.g. vascular obstruction or exposure to moderate cold - decrease blood flow to extremities-
Sites to look	All over the body Seen in Tongue	Fingertips, nail bed, extremities Not seen in Tongue
Warming extremities	No change (does not improve cya 	Disappears 



Relation between Hypoxia and cyanosis:

The intensity of cyanosis is not a reliable sign for the degree of hypoxia (both not run in parallel)

- 1- Cyanosis does not occur with some types of hypoxia as
 - o **Anemic hypoxia:** the total amount of Hb is low
 - o **Histotoxic hypoxia:** no reduce Hb.
 - o **CO poisoning:** due to the cherry red color of CO-Hb.
- 2- Person with excess red blood cells, as in **polycythemia**, has greater liability to become cyanotic, even under normal conditions, because he has great excess hemoglobin that can become deoxygenated.



Factors modify the color of the cyanosis:

1- Blood composition:

Amount of reduced Hb: Cyanosis increase with increased reduced Hb.

Presence of abnormal Hb

2- Skin

Thickness: cyanosis appears in thin skin e.g. nail beds, ear lobes.

Pigmentation: cyanosis is masked in dark races.



Match the following causes with central cyanosis, peripheral cyanosis or no cyanosis:

- **Hypoventilation** central cyanosis
no cyanosis
- **Anemia**
- **Diffusion impairment** central cyanosis
peripheral cyanosis
- **Congestive heart failure** cyanosis
peripheral cyanosis
- **Moderate cold** cyanosis
no cyanosis
- **Cyanide poisoning** no cyanosis

Summery



Hypoxia: it is lack of oxygen **at tissue level.**
Features

	Hypoxic hypoxia	Anemic Hypoxia	Stagnant Hypoxia	Histotoxic Hypoxia
PO ₂ in arterial blood	Reduced	Normal	Normal	Norma
Oxygen carrying capacity of blood	Normal	Reduced	Normal	Norma
Velocity of blood flow	Normal	Normal	Reduced	Normal
Utilization of oxygen by tissues	Normal	Normal	Normal	Reduced
Efficacy of oxygen	Highly beneficial	Less beneficial	Less beneficial	Not beneficial



1- Cyanosis Appear when the reduced Hb is above which of the following levels?

- A. 1 g/100ml capillary blood.
- B. 2 g/100ml capillary blood.
- C. 3 g/100ml capillary blood.
- D. 4 g/100ml capillary blood.
- E. 5 g/100ml capillary blood.



2- Which of the following causes of hypoxia characterized by high venous PO_2 ?

- A. Anemia.
- B. Impaired ventilation.
- C. Cyanide poisoning.
- D. CO poisoning.
- E. Venous obstruction.

SUGGESTED TEXTBOOKS



1. Ganong's Review of Medical Physiology, twenty-fifth edition 2016, McGraw-Hill Education, chapter 35, from page 646 to 653
2. Guyton and Hall textbook of medical physiology, thirteenth edition 2016, Elsevier, chapter 43 , from page 554 to 556

